CLAIMS

What is claimed is:

1. In a fuel reforming system of the type having a first reactor including an inlet in fluid communication with a fuel supply stream and an air supply stream and an outlet, a second reactor having an inlet in fluid communication with said first reactor outlet and a water supply stream and an outlet, a third reactor having an inlet in fluid communication with said second reactor outlet and a second air supply stream and an outlet, and a combustor having an inlet in fluid communication with said third reactor outlet, the improvement comprising a steam generation circuit for introducing a steam stream into said first reactor inlet, said steam generation circuit including:

a first flow path including a first heat exchanger element operably associated with said third reactor for vaporizing a first water stream to form a first vaporized water stream;

a second flow path having a second heat exchanger element operably associated with said combustor for vaporizing a second water stream to form a second vaporized water stream;

a mixing volume in fluid communication with said first and second flow paths such that said first and second vaporized water streams are combined to form said steam stream; and

a third flow path providing fluid communication from said mixing volume to said first reactor inlet.

2. The fuel reforming system of claim 1 wherein said third flow path further comprises a pressure regulator for regulating the pressure of said steam stream therein.

3. The fuel reforming system of claim 1 wherein said first flow path comprised an upstream heat exchanger interdisposed between said second reactor and said third reactor for transferring heat from a reformate stream exhaust from said second reactor to said first vaporized water stream prior to said reformate stream entering said third reactor and a downstream heat exchanger interdisposed between said third reactor and said combustor for transferring heat from said reformate stream to said first vaporized water stream prior to said reformate stream entering said combustor.

4. The fuel reforming system of claim 3 wherein said first flow path further comprises an internal heat exchanger disposed within said third reactor for transferring heat from said third reactor to said first vaporized water stream.

5. The fuel reforming system of claim 1 wherein said third flow path further comprises an internal heat exchanger disposed within said second reactor for transferring heat from said second reactor to said steam stream.

6. The fuel reforming system of claim 1 wherein said third flow path further comprises a heat exchanger operably associated with said first reactor for transferring heat from said first reactor to said steam stream.

7. The fuel reforming system of claim 6 wherein said third flow path further comprises a second mixing volume wherein a fourth water stream is mixed with said steam stream.

8. The fuel reforming system of claim 6 wherein said third flow path further comprises a second heat exchanger element operably associated with said first reactor for transferring heat from said steam stream to said first air supply stream.

9. The fuel reforming system of claim 1 further comprising a second mixing volume interdisposed between said first reactor outlet and said second reactor inlet wherein a third water stream is mixed with a reformate stream discharged from said first reactor outlet.

10. The fuel reforming system of claim 1 further comprising a second mixing volume interdisposed between said first air supply stream and said first reactor inlet, said third flow path being in fluid communication with said second mixing volume such that said steam stream and said first air supply stream are mixed upstream of said first reactor inlet.

11. The fuel reforming system of claim 1 wherein said first reactor is an autothermal reformer having a partial oxidation reactor section and a steam reforming reactor section, said second reactor is a water gas shift reactor and said third reactor is a preferential oxidation reactor.

12. A thermal management process for a fuel reforming system of the type including a first reactor having an inlet receiving a fuel supply stream and a first air supply stream and an outlet discharging a reformate stream, a second reactor having an inlet receiving said reformate stream and a water supply stream and an outlet discharging said reformate stream, a third reactor having an inlet receiving said reformate stream and a second air supply stream and an outlet discharging said reformate stream and a combustor, the method comprising the steps of:

transferring a first quantity of heat from said reformate stream passing through said third reactor to a first water stream to form a first vaporized water stream, thereby maintaining the temperature of said third reactor with a thermal operating range;

transferring a second quantity of heat from said combustor to a second water stream to form a second vaporized water stream;

combining said first and second vaporized water streams to form a steam stream; and

introducing said steam stream into said first reactor inlet.

13. The thermal management process of claim 12 further comprising the step of regulating the pressure of said steam stream at a predetermined pressure level, thereby controlling the temperature of said steam stream.

14. The thermal management process of Claim 12 wherein said thermal operating range of said third reactor is from about 150°C to about 200°C.

15. The thermal management process of Claim 12 wherein said predetermined pressure level is in the range of about 1 to 7 atmospheres absolute pressure.

16. The thermal management process of Claim 15 wherein said predetermined pressure range is approximately 3 atmospheres absolute pressure.

17. The thermal management process of Claim 12 further comprising the step of controlling the temperature of said reformate gas within said second reactor.

18. The thermal management process of Claim 17 wherein the step of controlling the temperature of said reformate gas within said second reactor by transferring a third quantity of heat from said second reactor to said steam stream.

19. The thermal management process of Claim 17 further comprising the step of controlling the temperature of said reformate gas within said second reactor by

injecting said water supply stream into said reformate gas upstream of said second reactor.

20. The thermal management process of Claim 12 further comprising the step of transferring a third quantity of heat from said reformate stream passing through said first reactor to said steam stream.

21. The thermal management process of Claim 20 further comprising the step of injecting a water stream into said steam stream prior to transferring said third quantity of heat from said reformate stream.

22. The thermal management process of Claim 12 further comprising the step of heating said first air supply stream with said steam stream.

23. The thermal management process of Claim 12 wherein said first reactor is an autothermal reforming reactor.

24. The thermal management process of Claim 12 wherein said third reactor is a preferential oxidation reactor.

25. The thermal management process of Claim 12 wherein said second reactor is a water gas shift reactor.

26. The thermal management process of Claim 25 wherein the water gas shift reactor has a high temperature shift stage and a low temperature shift stage.

27. The thermal management process of Claim 26 wherein the temperature of said reformate gas is controlled by spraying said water supply stream into said reformate gas prior to entering said high temperature shift stage.

28. The thermal management process of Claim 26 wherein the temperature of said reformate gas is controlled by injecting said water supply stream into said reformate gas prior to entering said low temperature shift stage.

29. A method of operating a fuel reforming system comprising the steps of:

reacting an air supply stream, a water supply stream and a fuel supply stream in an auto thermal reformer to form a reformate gas having a concentration of carbon monoxide;

introducing said reformate gas and a first air stream into a preferential oxidation reactor to lower said concentration of carbon monoxide;

heating a first water stream in said preferential oxidation reactor to form a first portion of vaporized water, the temperature of the preferential oxidation reactor being controlled by said first water stream;

heating a second water stream in a combustor to form a second portion of vaporized water,

mixing said first portion and said second portion of said vaporized water to form a steam stream which is mixed with said air supply stream for regulating the temperature of said reformate gas.

30. The method of operating a fuel reforming system of Claim 29 wherein said steam stream is mixed with said air supply stream prior to reaction within the auto thermal reformer.

31. The method of operating a fuel reforming system of Claim 29 wherein said second portion of said vaporized water comprises less than 50% of said steam stream.

32. The method of operating a fuel reforming system of Claim 29 wherein the said preferential oxidation reactor operates within a temperature range of between 100°C and 150°C.

33. The method of operating a fuel reforming system of Claim 32 further comprising the step of regulating the pressure of said steam stream prior to said auto thermal reactor for controlling the temperature thereof.

34. The method of operating a fuel reforming system of Claim 29 further comprising the step increasing the flow rate of at least one of said first water stream and said second water stream prior to increasing the flow rate of said fuel supply stream in response to an increased reformate gas flow demand.

35. The method of operating a fuel reforming system of Claim 29 wherein said combustor is operated below a maximum vaporization capacity during a steady-state operation, thereby providing a thermal mass for additional vaporization capacity in response to an increase reformate gas flow demand.

36. The method of operating a fuel reforming system of Claim 29 further comprising the step of temporarily increasing the flow rate of said fuel supply stream to a rate greater than a target rate required to respond to an increased reformate gas flow demand.

37. A method of operating a fuel reforming system comprising the steps of:

reacting an air supply stream, a steam stream and a fuel supply stream in the auto thermal reformer to form a reformate gas having a concentration of carbon monoxide;

processing said reformate gas from said auto thermal reformer in a water gas shift reactor to reduce said concentration of carbon monoxide gas;

introducing said reformate gas and an air stream into a preferential oxidation reactor to lower said concentration of carbon monoxide gas;

heating a first water stream with said reformate gas prior to entering said preferential oxidation reactor, thereby cooling said reformate gas and forming a first portion of vaporized water;

heating a second water stream in a combustor to form a second portion of vaporized water, and

mixing said first portion and said second portion of said vaporized water to form a steam stream; and

38. The method of operating a fuel reforming system of claim 37 further comprising the step of controlling the temperature of said water gas shift reactor with said first portion of said vaporized water.

39. The method of operating a fuel reforming system of Claim 37 wherein the pressure of said first portion of vaporized water is regulated at a substantially constant level.

40. The method of operating a fuel reforming system of Claim 37 wherein said first portion of said vaporized water comprises about 50% to about 70% of said steam fluid.

41. The method of operating a fuel reforming system of Claim 37 wherein said first portion and said second portion of said vaporized water and said steam stream flow through said fuel processor in a generally opposite direction relative to said reformate gas.

42. The method of operating a fuel reforming system of Claim 37 wherein a portion of said steam stream is mixed with said air supply stream prior to entering said auto thermal reformer.

43. The method of operating a fuel reforming system of Claim 37 wherein said steam stream is mixed with said fuel supply stream to atomize said fuel supply stream prior to entering said auto thermal reformer.

44. The method of operating a fuel reforming system of Claim 36 further comprising the step increasing the flow rate of at least one of said first water stream and said second water stream prior to increasing the flow rate of said fuel supply stream in response to an increased reformate gas flow demand.

45. The method of operating a fuel reforming system of Claim 36 wherein said combustor is operated below a maximum vaporization capacity during a steady-state operation, thereby providing a thermal mass for additional vaporization capacity in response to an increase reformate gas flow demand.

46. The method of operating a fuel reforming system of Claim 36 further comprising the step of temporarily increasing the flow rate of said fuel supply stream to a rate greater than a target rate required to respond to an increased reformate gas flow demand.